Integrating Earth Observations with Improved Topoclimate and Connectivity Tools to inform Climate-Smart Conservation (Y2, Q1 update)

The Nature Conservancy
Protecting nature. Preserving life.

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April 25, 2018

Outline – updating CNS mapping

Background and complexity of the decision context (multiple levels of decisions, plus modifying the plane while it's flying)…

Earth Observations, considered two ways:

- Using NASA data to improve an analysis component

- Improving Circuitscape, a key tool in our work and many other connectivity-related analyses, so that it is better able to handle NASA datasets.

Goal – ideas on what else can we do to expand collaboration between NGOs and remote sensing/EO experts.

The Nature Conservancy

Protecting nature. Preserving life.

The **mission** of The Nature Conservancy is to conserve the lands and waters on which all life depends

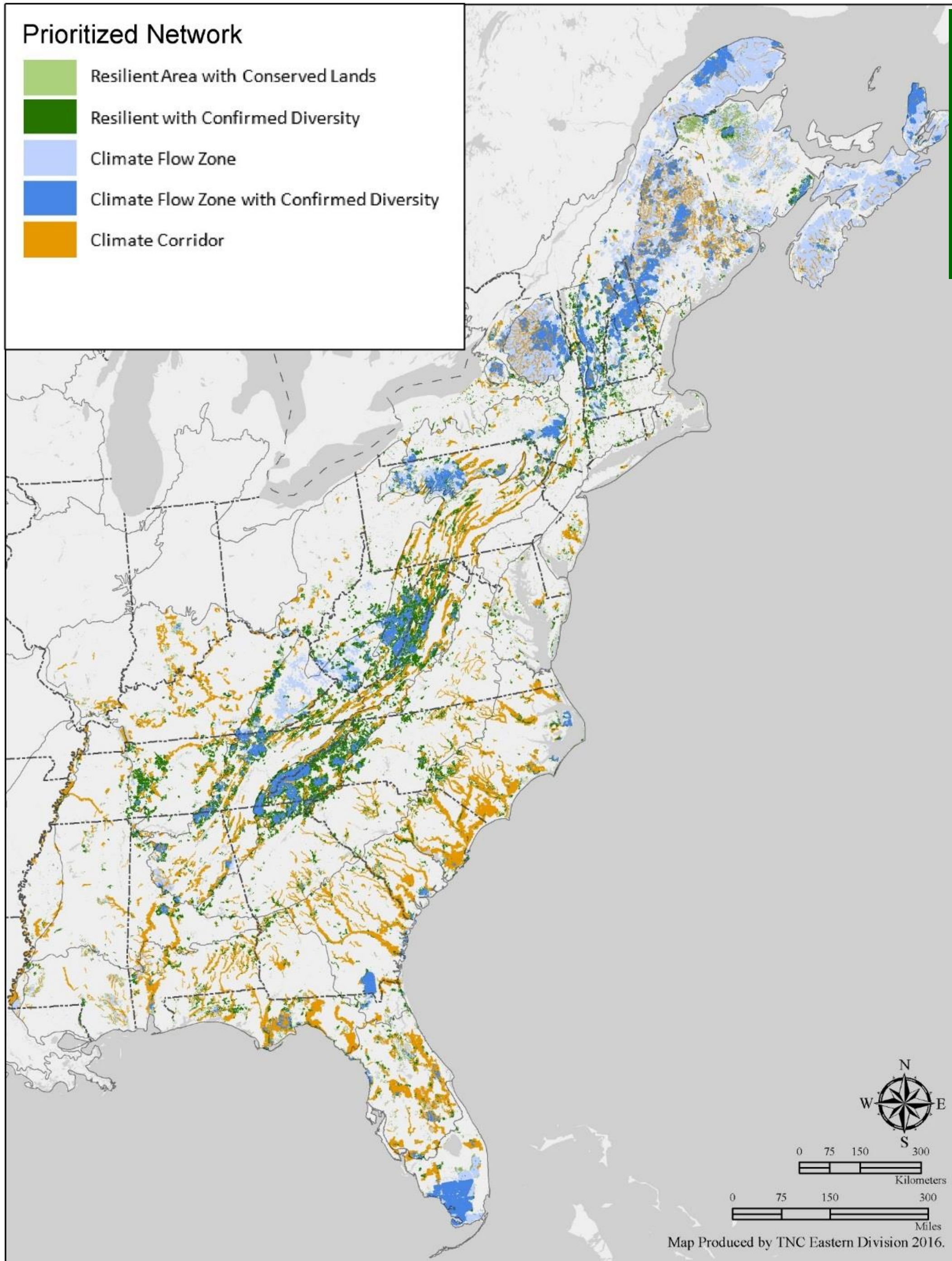
- Founded in 1951 – 67 yrs. of integrating science & practice.
- More than 600 scientists, 2000+ staff total.
- Largest land trust. Over 120,000,000 acres conserved.

Decision – where do we protect land?

Context: In the US, most staff are organized into state chapters. State conservation planners & land protection staff are the decision-makers.

Approach recently incorporated in TNC's US Protection Strategy

Co-developed maps of Resilient and Connected networks



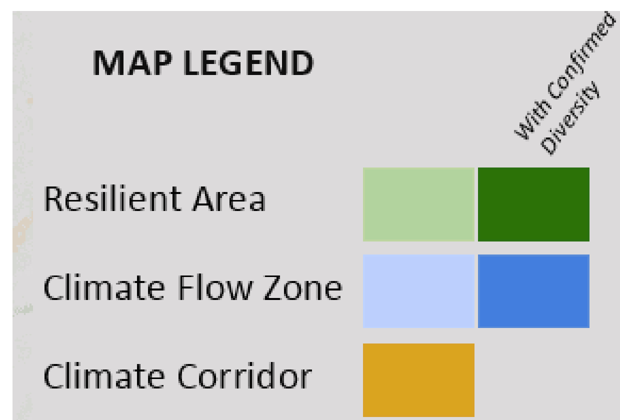
Resilience (38%)

Resilience + Flow

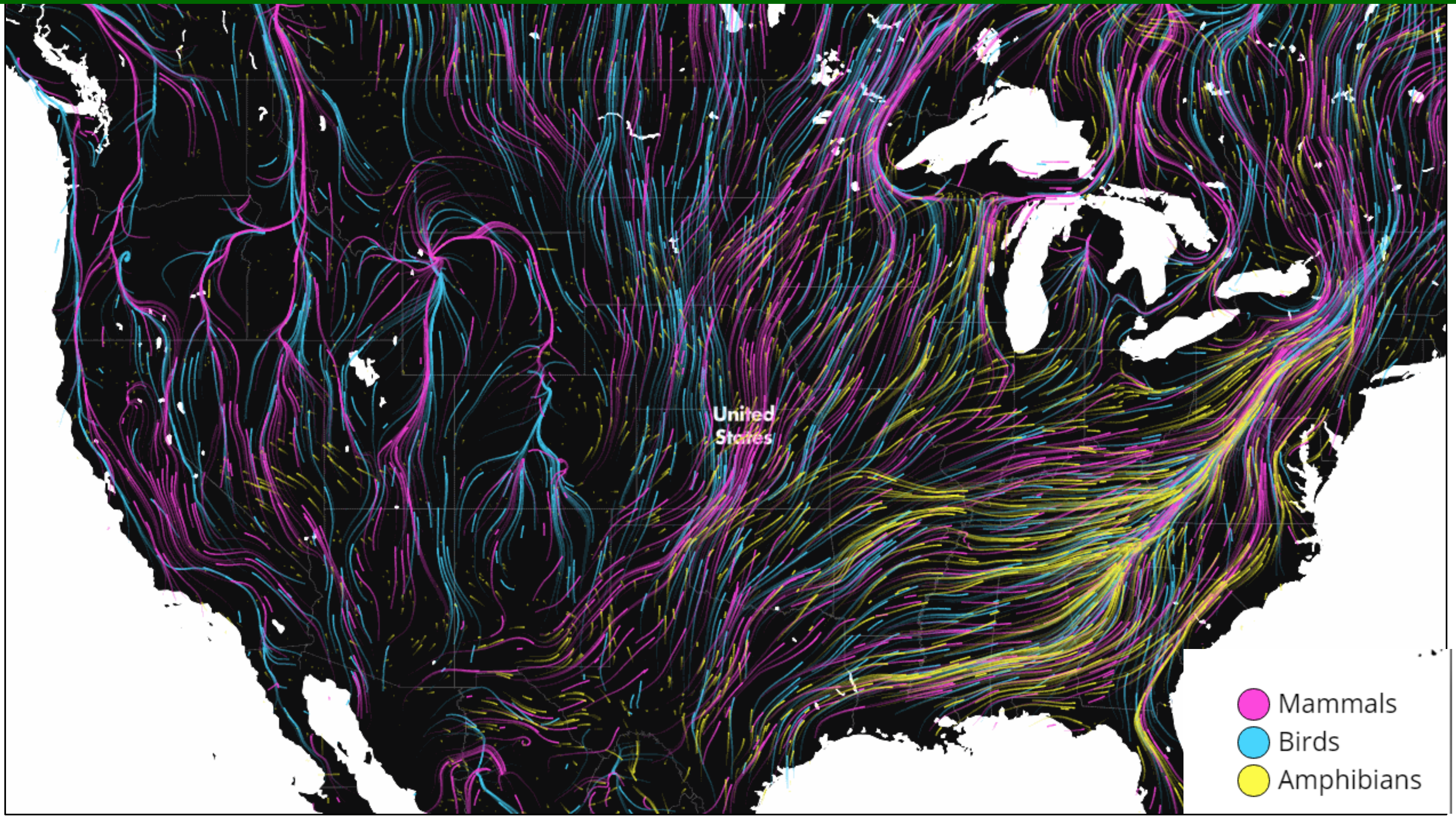
Resilience + Flow + Diversity

Prioritized (23%)

all settings
80,000 species/community
maximum flow
44% protected



Where do we invest in land protection strategies under climate change?



Data source: Lawler, J. J., A. S. Ruesch, J. D. Olden, and B. H. McRae. 2013. Projected climate-driven faunal movement routes. Ecology Letters **16**:1014-1022.

Niche models + Circuitscape connectivity. Animation by Dan Majka, TNC

Conserving Nature's Stage – 3 components

1. Geodiversity (stages)

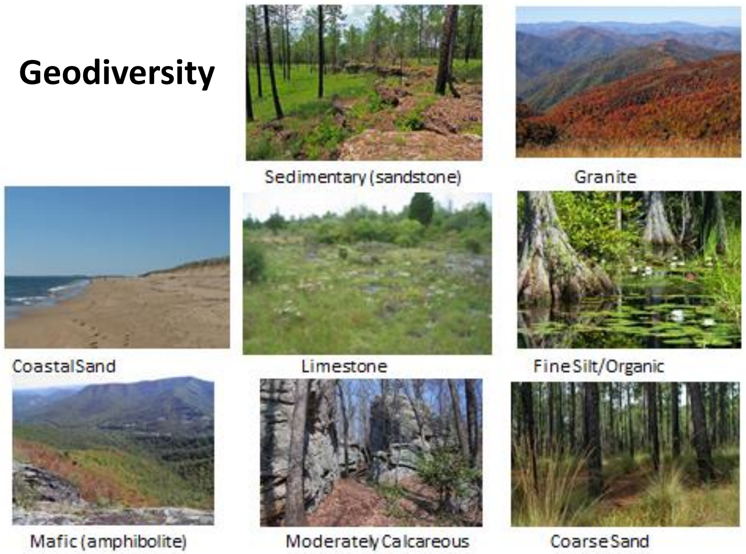
Stratify by geology/soils – goal is representation across all types.

2. Identify topographically complex and locally intact sites

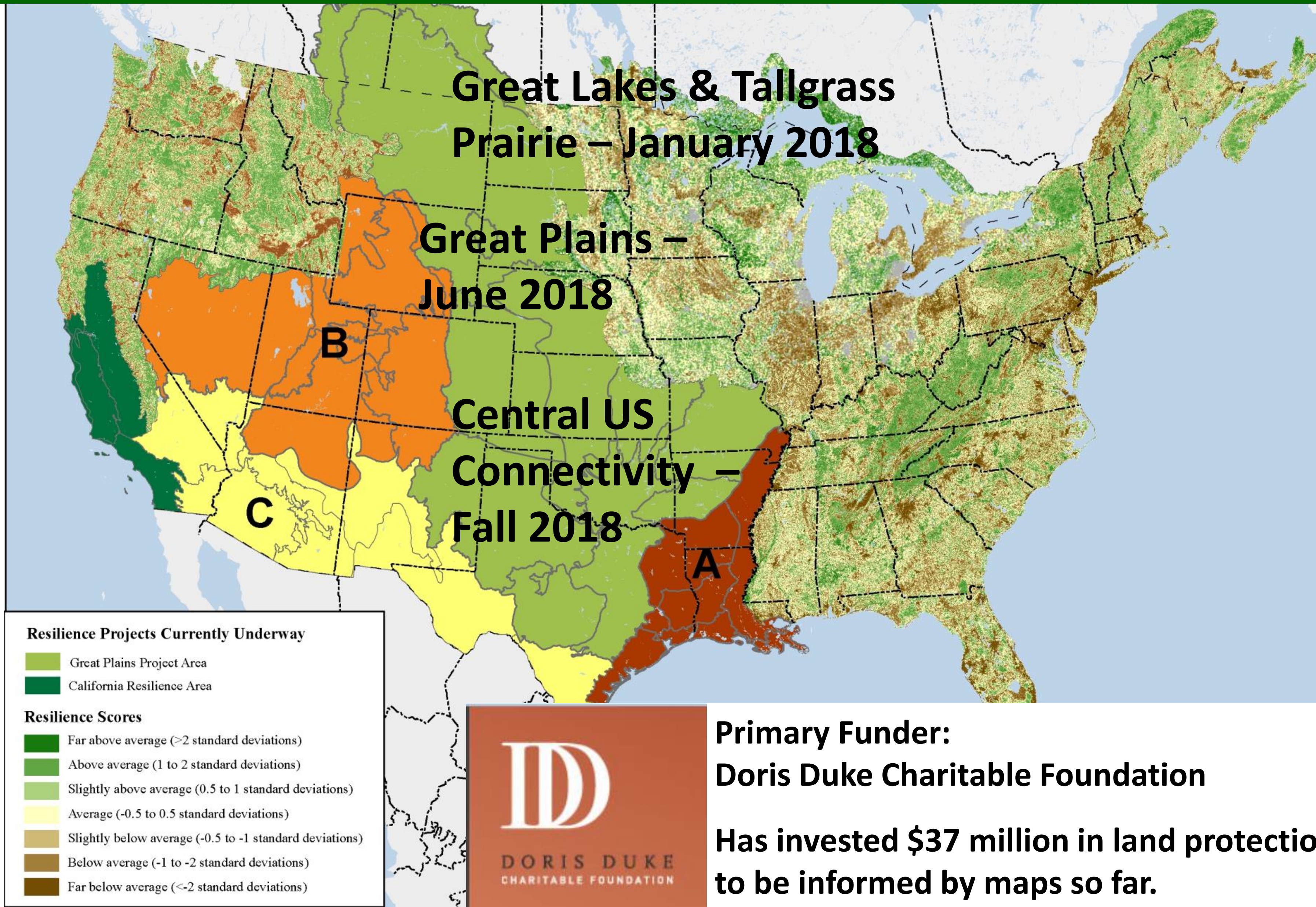
These "resilient sites" provide more climate options for current & future biodiversity & should act as biodiversity strongholds.

3. Regional flow/connectivity.

Invest in connected sites that maintain flow (larger-scale movement options)



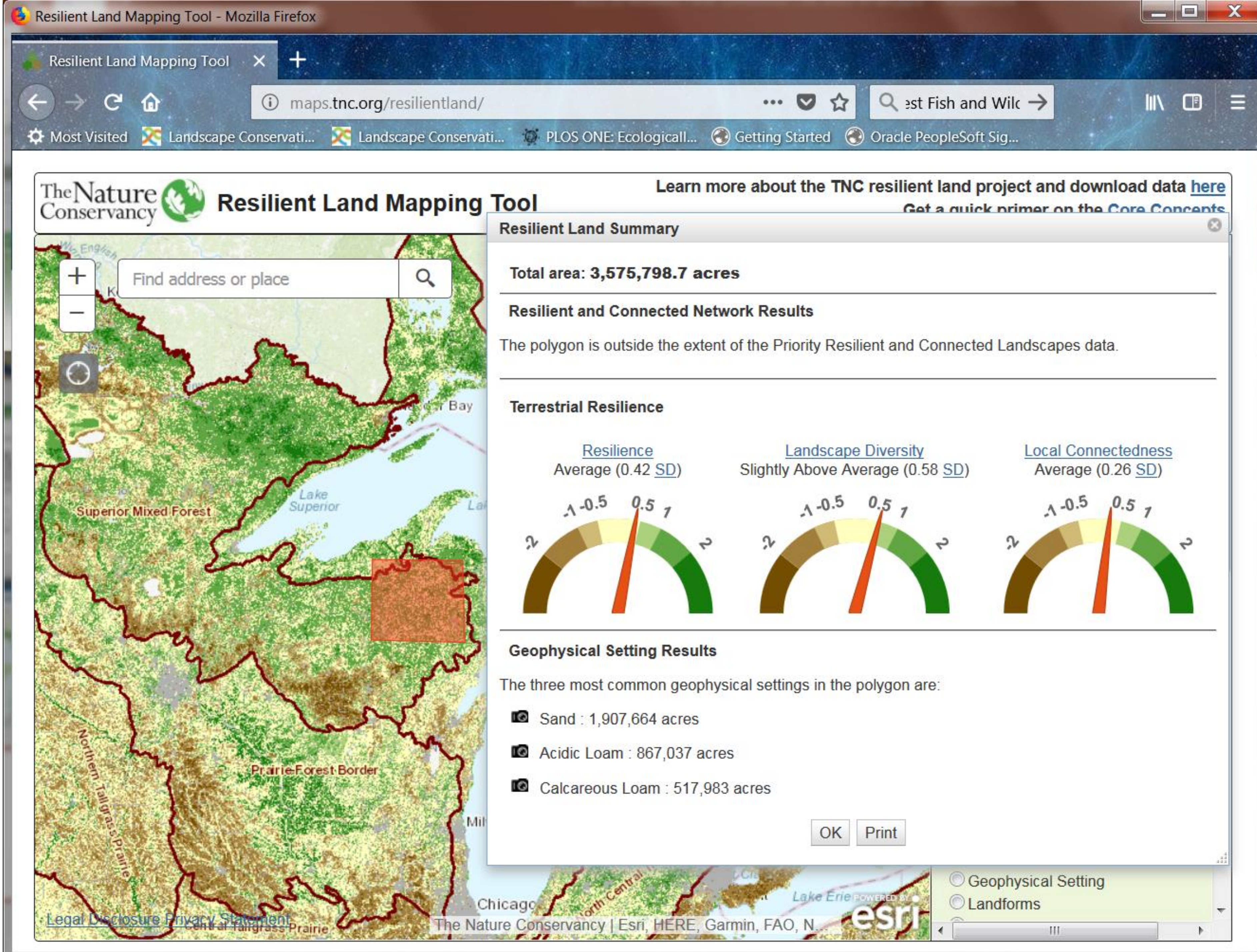
An ongoing process, started about 2008



DORIS DUKE CHARITABLE FOUNDATION

Primary Funder:
Doris Duke Charitable Foundation

Has invested $37 million in land protection to be informed by maps so far.


Resilient Land Mapping Tool - Mozilla Firefox
Resilient Land Mapping Tool
maps.tnc.org/resilientland/
Most Visited
Landscape Conservati...
Landscape Conservati...
PLOS ONE: Ecologicall...
Getting Started
Oracle PeopleSoft Sig...
The Nature Conservancy
Resilient Land Mapping Tool
Learn more about the TNC resilient land project and download data here
Find address or place
Resilient Land Summary
Total area: 3,575,798.7 acres
Resilient and Connected Network Results
The polygon is outside the extent of the Priority Resilient and Connected Landscapes data.
Terrestrial Resilience
Resilience
Average (0.42 SD)
Landscape Diversity
Slightly Above Average (0.58 SD)
Local Connectedness
Average (0.26 SD)
-2
-1
-0.5
0.5
1
2
Geophysical Setting Results
The three most common geophysical settings in the polygon are:
Sand : 1,907,664 acres
Acidic Loam : 867,037 acres
Calcareous Loam : 517,983 acres
OK
Print
Lake Superior
Superior Mixed Forest
Prairie-Forest Border
Northern Tallgrass Prairie
Chicago
Lake Erie
Geophysical Setting
Landforms
Legal Disclosure
Privacy Statement
The Nature Conservancy | Esri, HERE, Garmin, FAO, N...
esri

CNS project team from TNC (Co-development/Sci/GIS)

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North America

Mark Anderson
Eastern Division

Meredith Cornett
MN/ND/SD

Jim Platt –
North America

Melissa Clark –
Eastern Division

Arlene Olivero Sheldon
Eastern Division

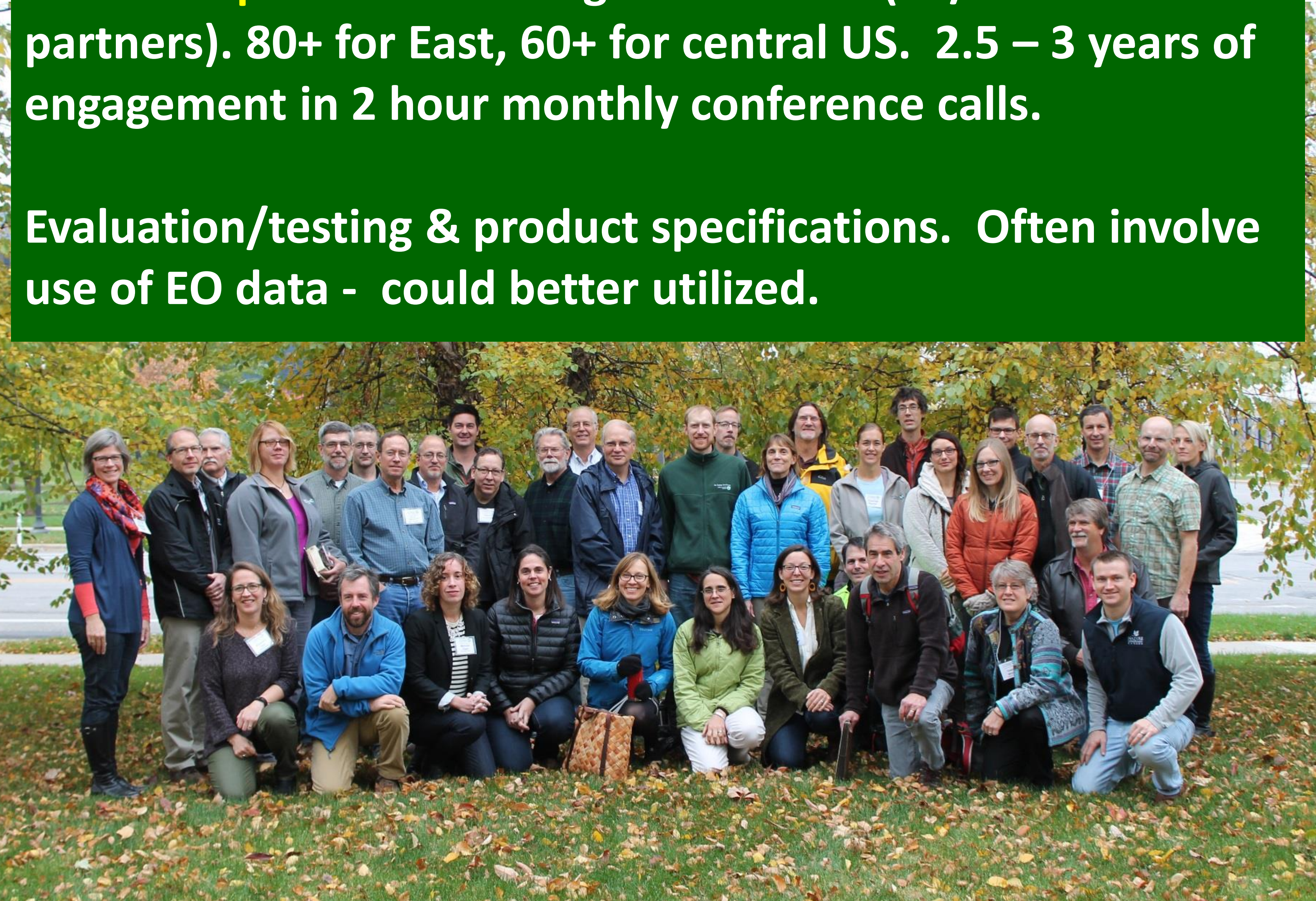
John Prince –
Eastern Division

We dedicate this work and all the good conservation that grows from it to Brad McRae (1966-2017)

Developer of Circuitscape and many other tools – brilliant scientist; prankster, mentor, and friend. He was the original PI for this grant.

Co-developed with steering committees (50/50 TNC & partners). 80+ for East, 60+ for central US. 2.5 – 3 years of engagement in 2 hour monthly conference calls.

Evaluation/testing & product specifications. Often involve use of EO data - could better utilized.



NASA grant collaborators – strengthening our science

1. Mapping topoclimate & testing our assumptions:

- *Solomon Dobrowski, University of Montana*

2. Updating our approach to local connectivity/human modifications

- *David Theobald, Senior Scientist, Conservation Science Partners Inc.*

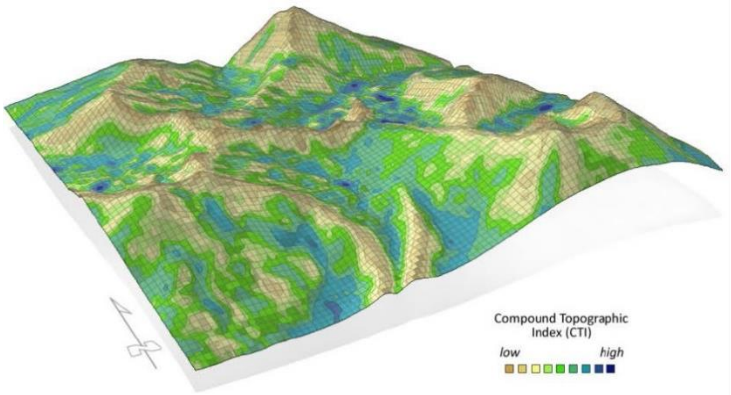
3. Recoding and improving Circuitscape

- Viral Shah, Co-creator of Circuitscape, and Ranjan Anantharaman, lead programmer, Julia Computing, Inc.
- Alan Edelman, Professor of Applied Mathematics, Massachusetts Institute of Technology
- Josh Lawler, Professor of Sustainable Resource Sciences, University of Washington

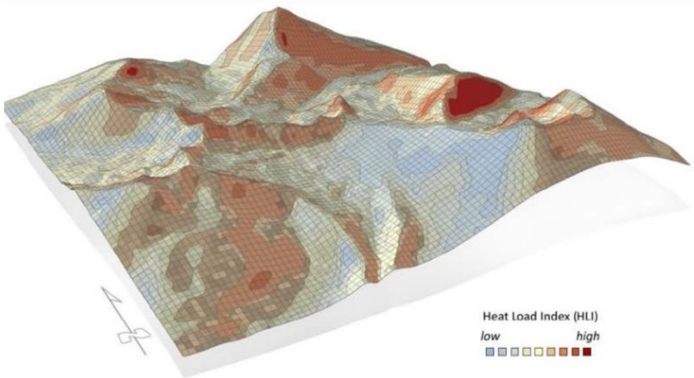
Earth Observation Data – used in products & for testing

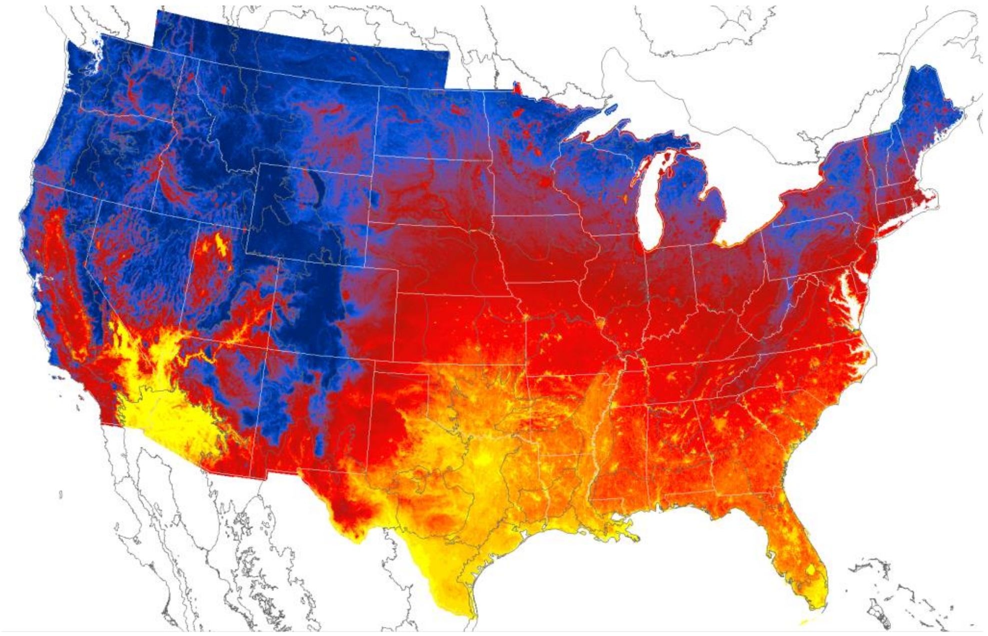
Term	Variable	Data Source	Notes
land surface temperature	LST_{day} LST_{night}	**MODIS Aqua MYD11A2 8 day Landsat**	monthly climatological means
x,y,z	Latitude, longitude, elevation	**SRTM NASA v3; NASADEM**	
land surface	NDVI	**MODIS Terra MOD13A3**	10-year (2003-12) monthly means
	Snow	**MODIS Terra MOD10A2 8-day snow cover product**	10-year (2003-12) monthly means
terrain variables	SRAD	Derived from DEM above	Monthly mean clear sky radiation
	TPI	Derived from DEM	Topographic position index
	CTI	Derived from DEM	Topographic wetness index
	HLI	Derived from DEM	Heat load index
land cover	NLCD	**USGS NLCD**	USGS land use and land cover product derived from **Landsat TM**
night lights	DMSP and VIIRS	**DMSP-OLS Nighttime Lights Time Series**	To be updated with **NASA VIIRS** when annual composite available

How well do our indices based on terrain metrics indicate microclimate diversity?



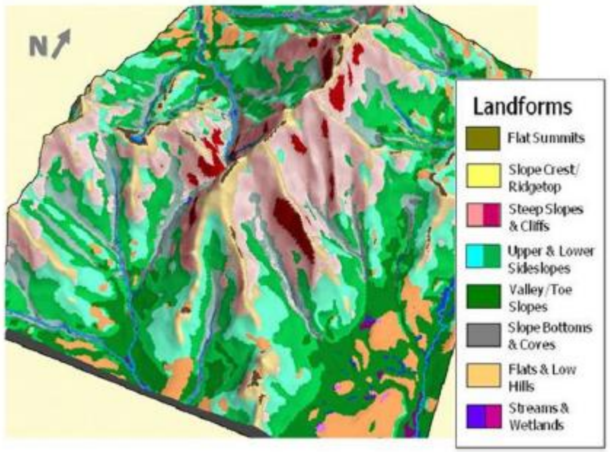
LST: allows testing using actual temperature data





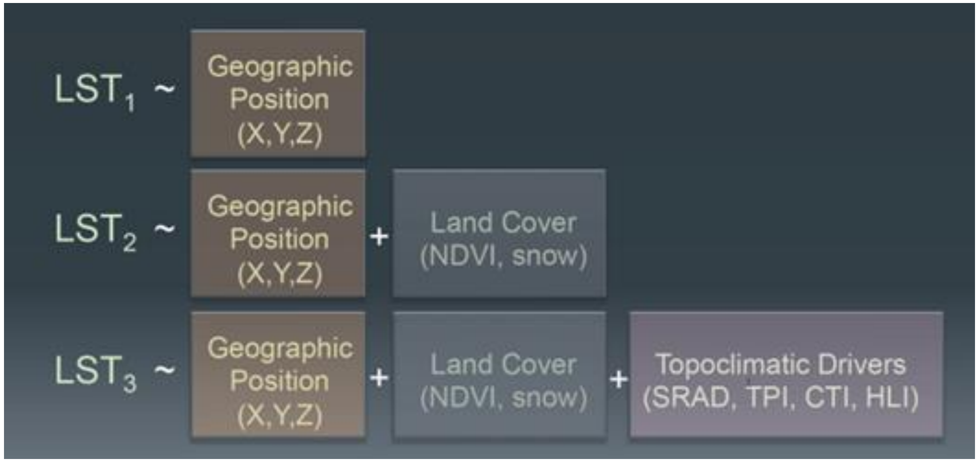
MODIS data on Land Surface Temp

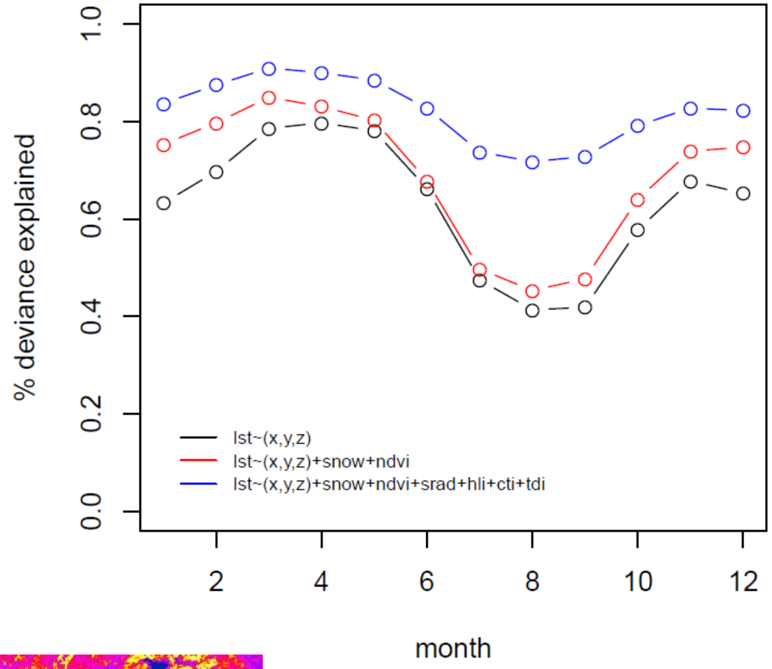
All Landforms

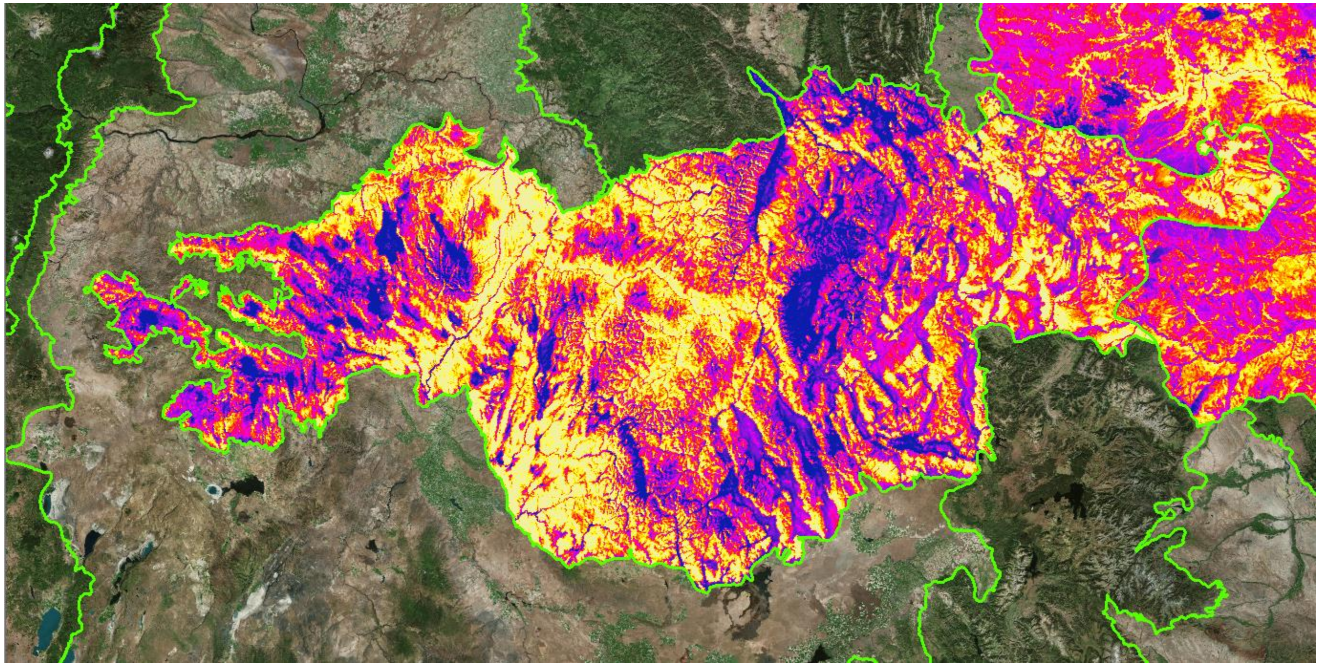


Modeling & data exploration - MODIS

Land surface temp (LST) model components:

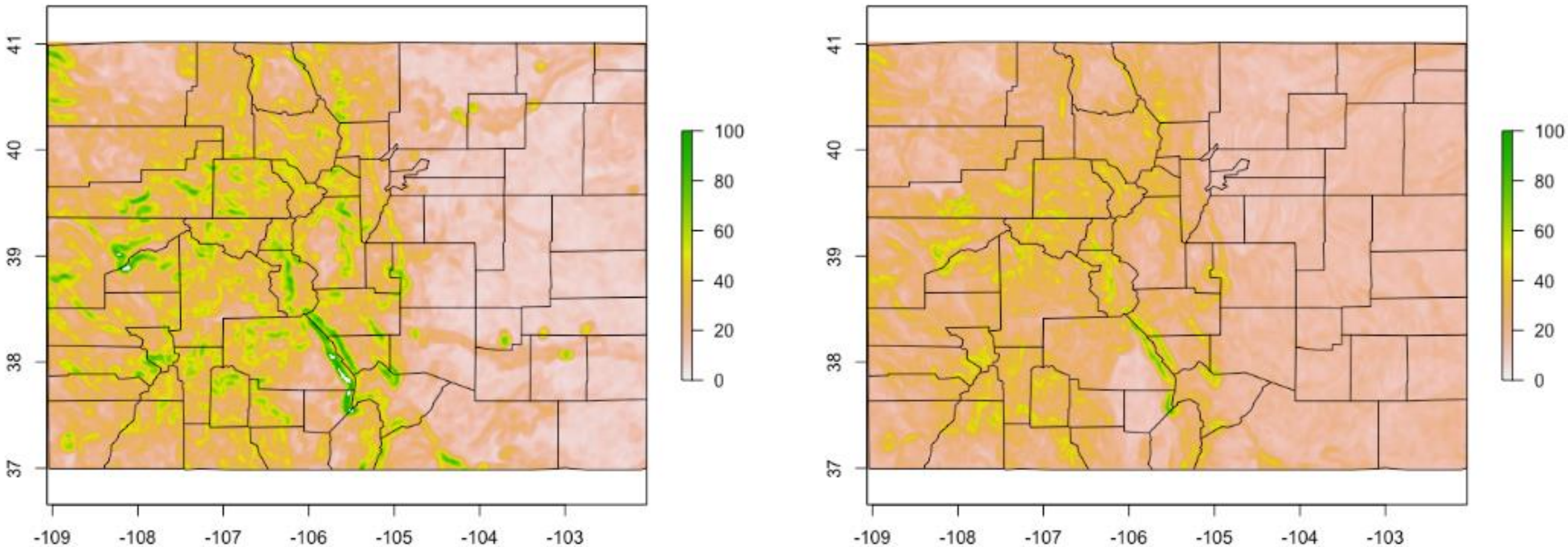






Example: July nighttime LST, Middle Rockes-Blue Mountains ecoregion

Example from Dobrowski's work – generating microclimate diversity estimates independent of vegetation from the best performing model



Observed MODIS LST variance (left) and predicted LST variance (right) from GLM models for the state of Colorado.

Just the variance from terrain (not vegetation) – should we weight this metric differently in the eastern half (a prairie ecoregion?)

(2) Tool improvement - Circuitscape

Evolution, 60(8), 2006, pp. 1551–1561

ISOLATION BY RESISTANCE

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Abstract.—Despite grow
available to incorporate
have typically either ass
to compensate for heter
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maps, simple maps of
barriers of differing qu
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structuring, and predict

Key words.—Gene flow
genetics, resistance dist

CONCEPTS & SYNTHESIS

EMPHASIZING NEW IDEAS TO STIMULATE RESEARCH IN ECOLOGY

Ecology, 89(10), 2008, pp. 2712–2724

USING CIRCUIT THEORY TO MODEL CONNECTIVITY IN ECOLOGY, EVOLUTION, AND CONSERVATION

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Abstract. Connectivity among populations and habitats is important for a wide range of ecological processes. Understanding, preserving, and restoring connectivity in complex landscapes requires connectivity models and metrics that are reliable, efficient, and process based. We introduce a new class of ecological connectivity models based in electrical circuit theory. Although they have been applied in other disciplines, circuit-theoretic connectivity models are new to ecology. They offer distinct advantages over common analytic connectivity models, including a theoretical basis in random walk theory and an ability to evaluate contributions of multiple dispersal pathways. Resistance, current, and voltage calculated across graphs or raster grids can be related to ecological processes (such as individual movement and gene flow) that occur across large population networks or landscapes. Efficient algorithms can quickly solve networks with millions of nodes, or landscapes with millions of raster cells. Here we review basic circuit theory, discuss relationships between circuit and random walk theories, and describe applications in ecology, evolution, and conservation. We provide examples of how circuit models can be used to predict movement patterns and fates of random walkers in complex landscapes and to identify important habitat patches and movement corridors for conservation planning.

Key words: circuit theory; dispersal; effective distance; gene flow; graph theory; habitat fragmentation; isolation; landscape connectivity; metapopulation theory; reserve design.

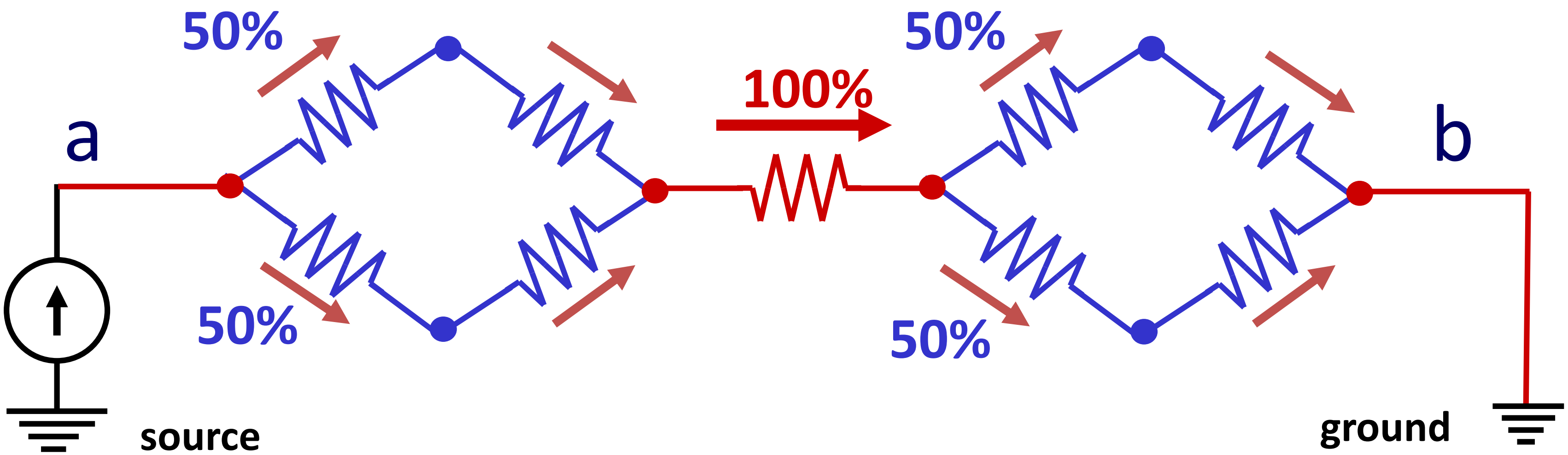
Circuitscape.jl

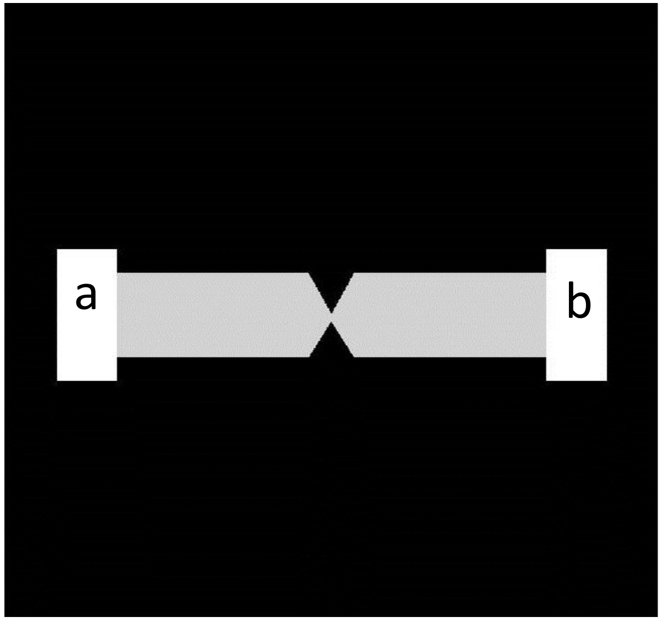
Implementation of Circuitscape in the Julia language

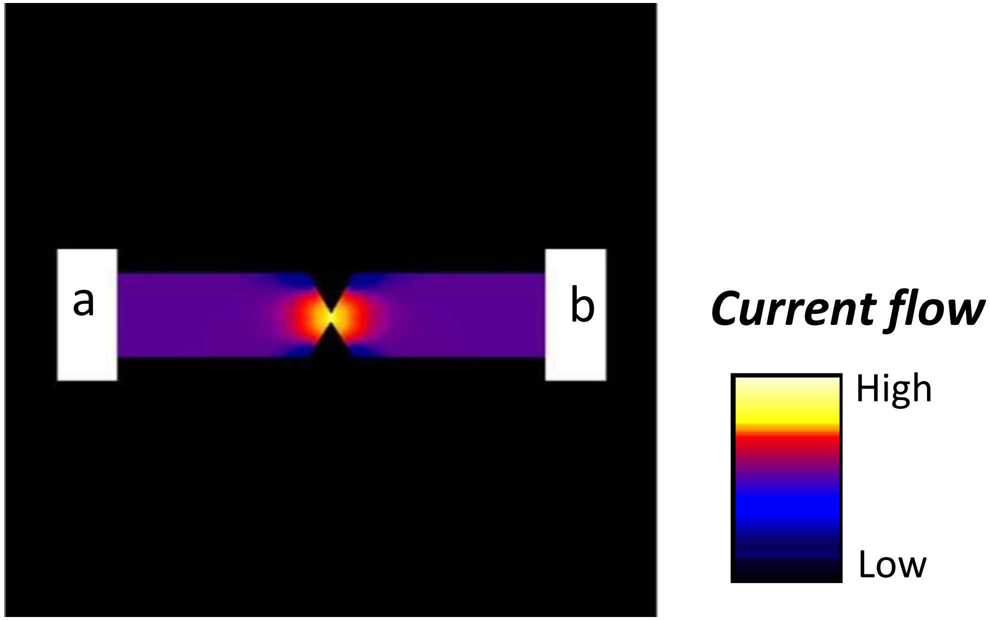
Julia computing

Applications: Landscape genomics, species movement/landscape connectivity, fire behavior, disease spread, human migrations…

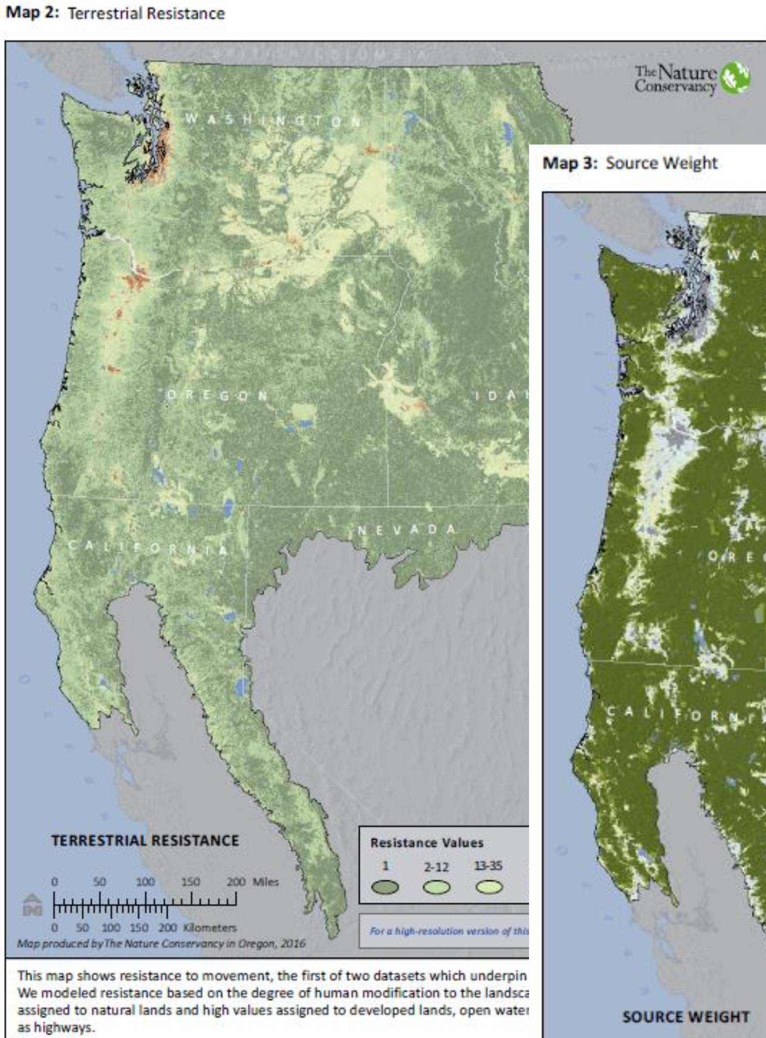
Current flow and connectivity mapping

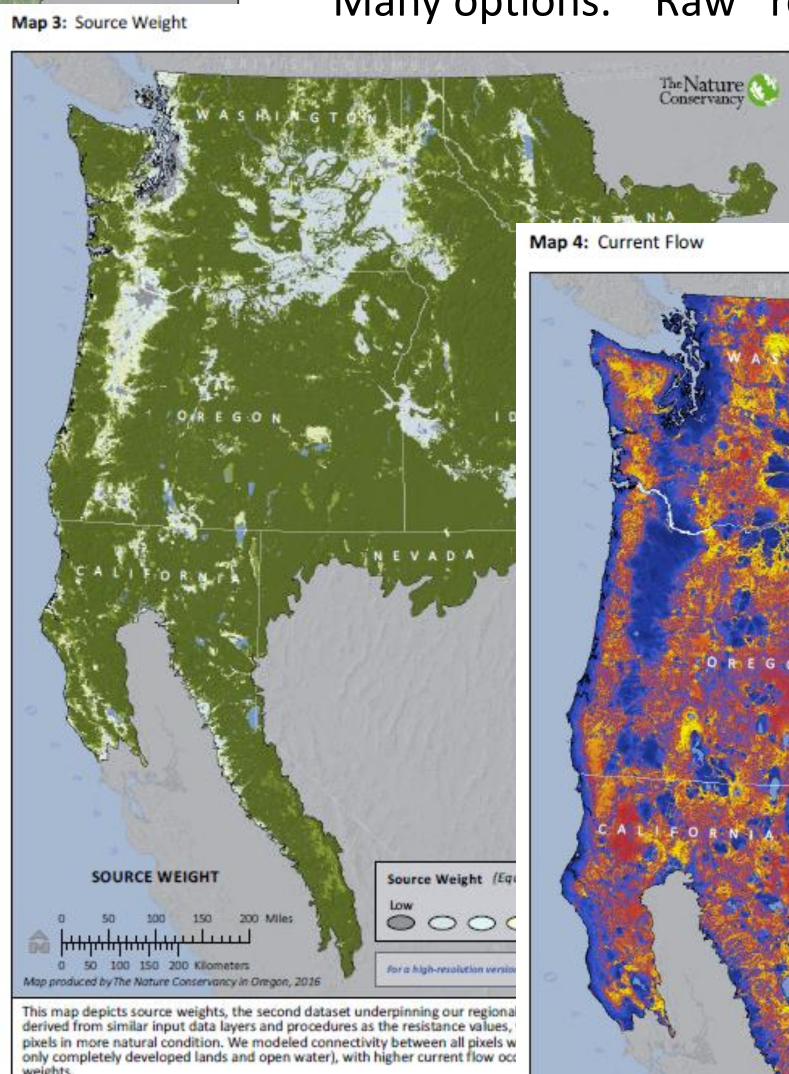


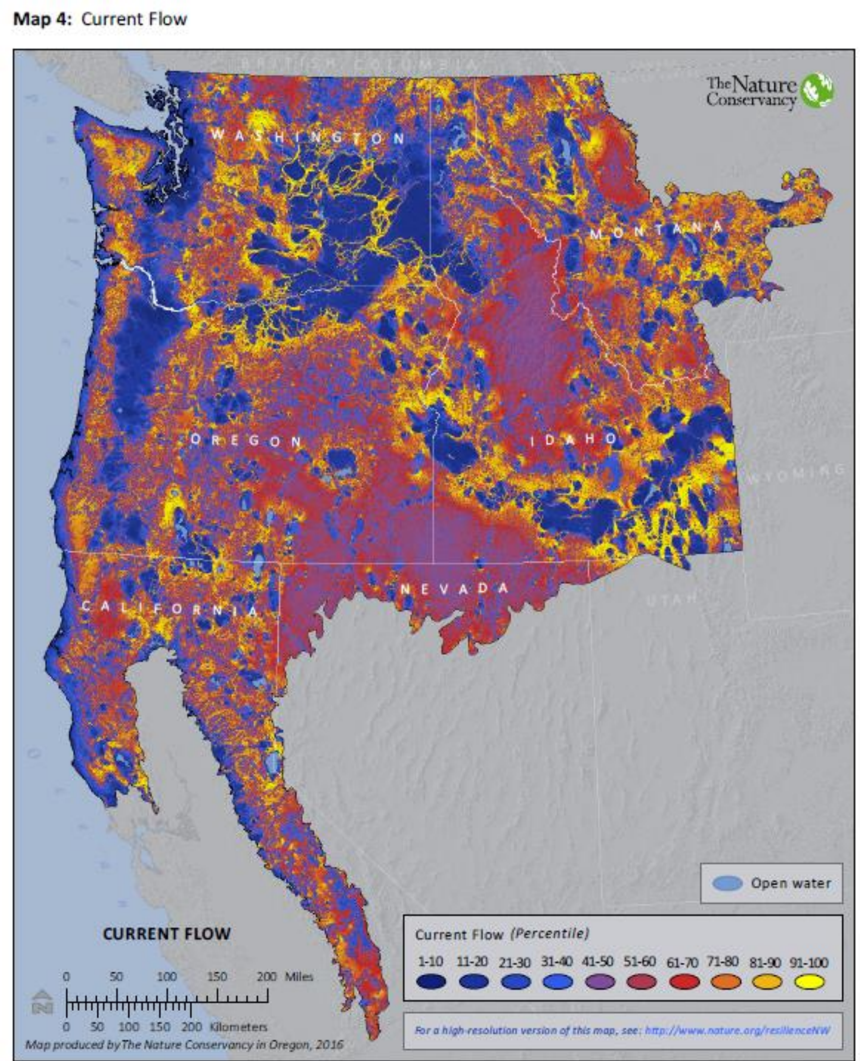




Need a resistance grid & source & grounds.
Many options. "Raw" results is current flow.

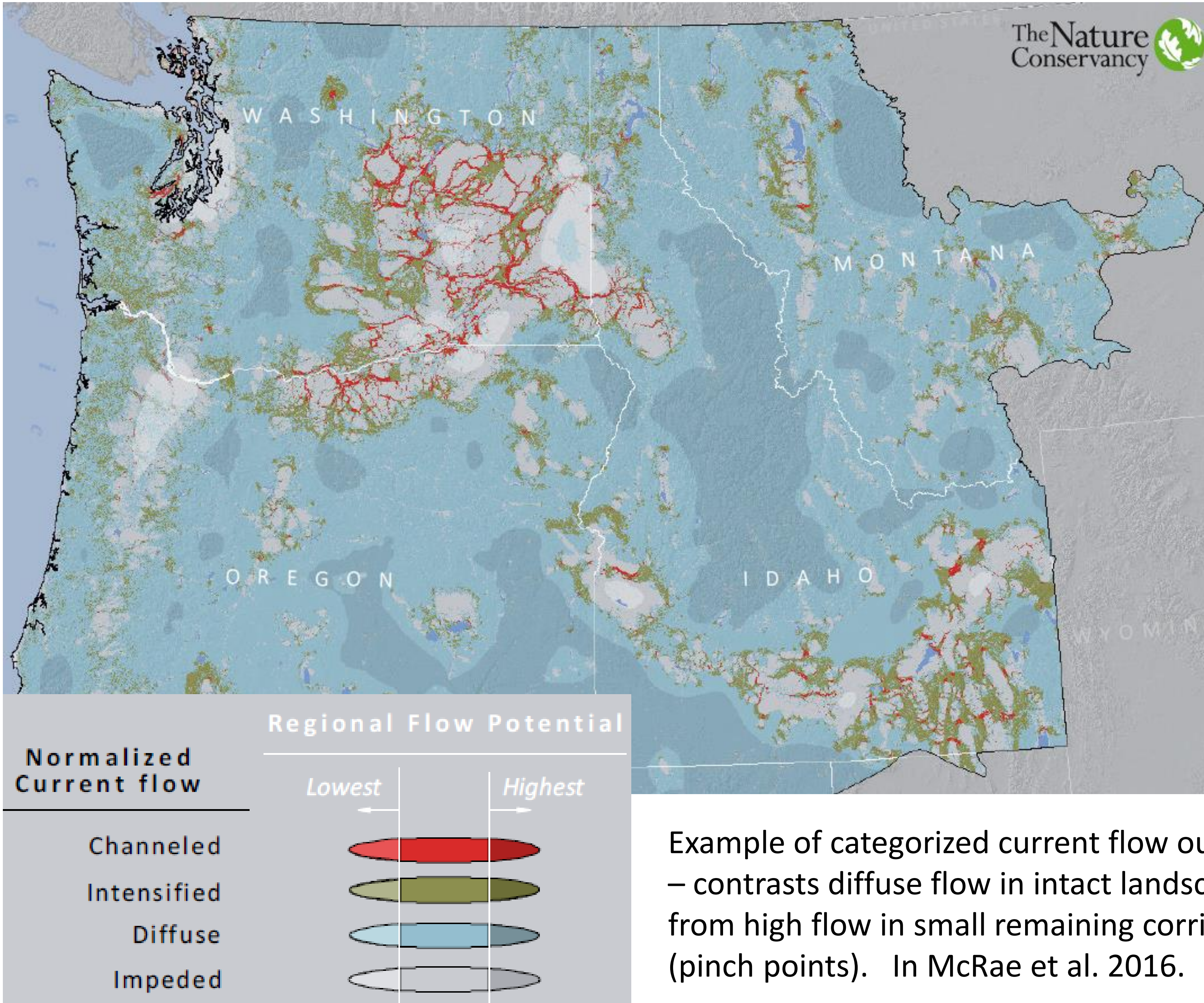






Key innovation = identification of multiple pathways, gradients

Source: McRae et al. 2016



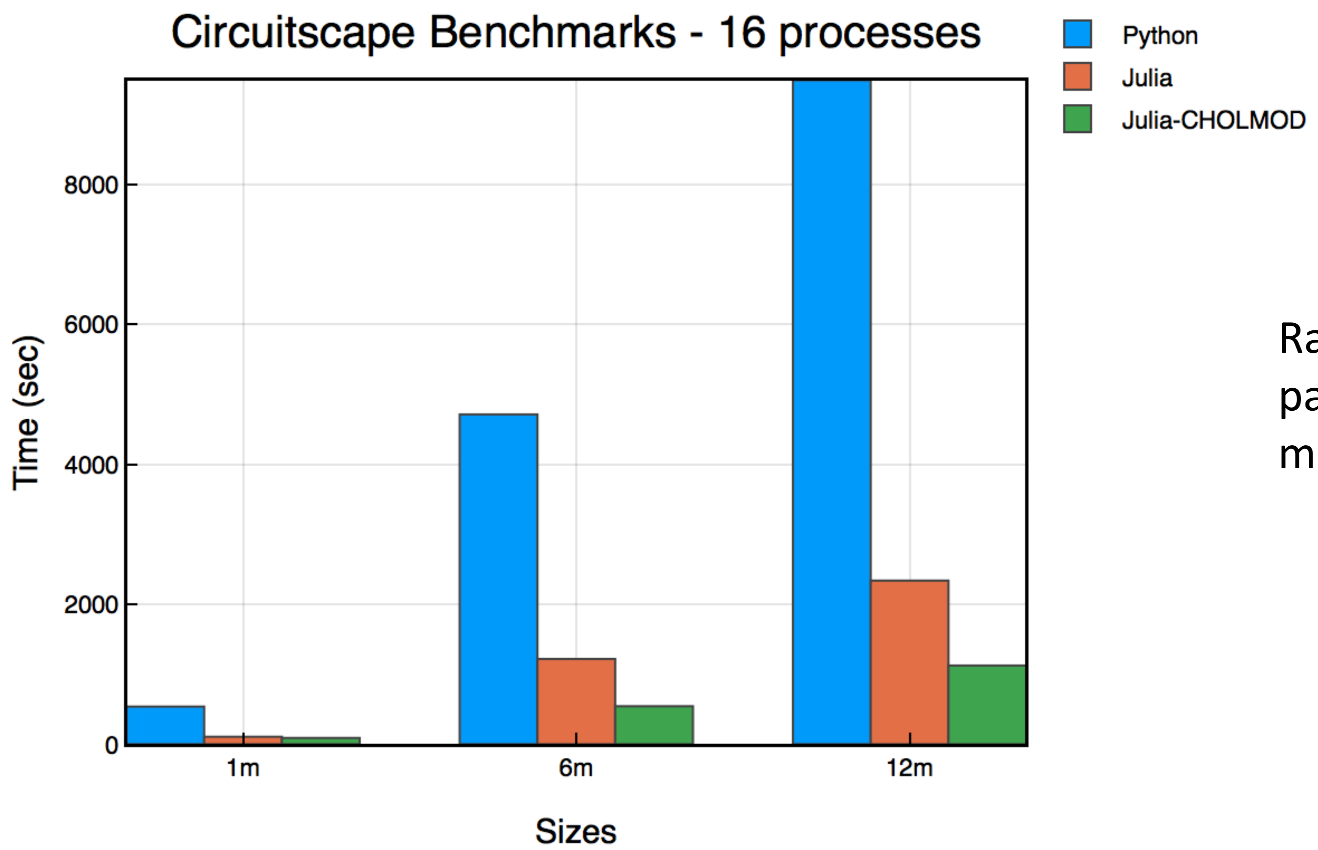
Example of categorized current flow outputs – contrasts diffuse flow in intact landscapes from high flow in small remaining corridors (pinch points). In McRae et al. 2016.

Circuitscape status update – Julia Computing

Full original Circuitscape functionality has been recoded in Julia language. Installation "packaging" coming soon. https://github.com/Circuitscape/Circuitscape.jl

- This provides parallelism on all platforms (Windows, Mac and Linux). Previously parallelism on Windows was constrained by limitations of Python – and our survey suggests most users (esp. non academic) are on Windows.
- New Solver Mode – CHOLMOD. Performs cholesky decomposition on the graph constructed. To use, include in INI file, choose solver = cholmod
- Single Precision Support (Experimental); saves memory, but at the cost of accuracy. Use it by including in the INI file: precision = single.
- Experimental cloud version coming soon – on MS Azure.

Speed testing



Raster pairwise mode

Run on a Linux (Ubuntu) server machine with the following specs:

- **Name**: Intel(R) Xeon(R) Silver 4114 CPU
- **Clock Speed**: 2.20GHz
- **Number of cores**: 20
- **RAM**: 384 GB

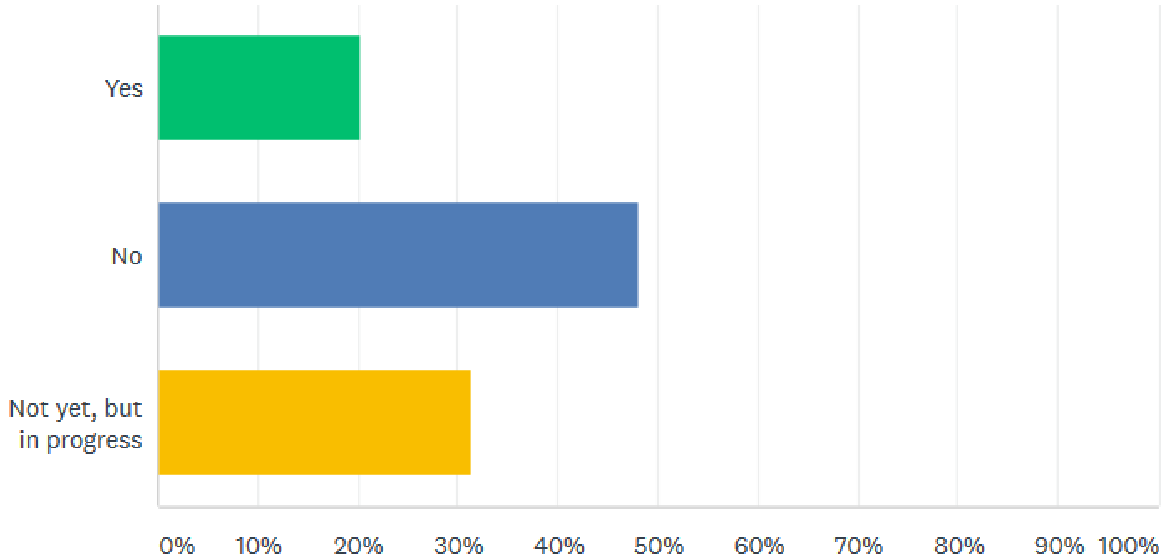
User survey – use, challenges, opportunities

Q9

Customize Export

Has your work with Circuitscape ever been used to inform a specific conservation, resource management, or public health decision?

Answered: 54 Skipped: 0



Our survey includes questions on where the tool is being used to inform decisions. These are key areas for work on how to incorporate Earth Observations.

CNS Resources:

TNC Gateway page: Reports, data, etc.
http://www.nature.ly/TNCResilience

Webmapper
http://maps.tnc.org/resilientland/

Story map for Great Lakes/Tallgrass
http://arcg.is/1SC9jL